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A cm-wave excess over free-free emission in planetary nebulae

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Abstract. A byproduct of experiments designed to map the CMB is the detection of a new component of foreground galactic emission. The anomalous foreground at 10-30 GHz, unexplained by traditional emission mechanisms, correlates with 100μm dust emission, and is thus presumably due to dust. We present evidence obtained with the CBI and SIMBA+SEST supporting the existence of a 31GHz excess over free-free emission in PNe. Possible interpretations involve a spinning dust component or 1 mm extinction due to metallic needles.

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An increasing amount of evidence supports the existence of a new continuum emission mechanism in the diffuse interstellar medium (ISM) at 10–30 GHz (Leitch *et al.* 1997). As proposed by Draine & Lazarian (1998) a candidate emission mechanism is electric dipole radiation from spinning very small grains (VSGs), or spinning dust. Examples in specific objects have been found by Finkbeiner (2004), Casassus *et al.* (2004), Watson *et al.* (2005), Casassus *et al.* (2006). Here we report on CBI and SEST+SIMBA observations of PNe.

The CBI is an interferometer array with 13 antennas mounted on a 6 m tracking platform. Its synthesized beam is ∼6 arcmin, and it covers 26–36 GHz in 10×1 GHz channels. We extracted flux densities by fitting parametrized models, discarding PNe with contaminating emission within the primary beam of 45 arcmin FWHM, as revealed by reduced χ^2 higher than ∼1.5. Independent integrations on different nights corroborate the uncertainties. Spectral indices over 26–36 GHz are all consistent with free-free emission, with $\alpha = -0.15$ ($F(\nu) = F(\nu_\circ)(\nu/\nu_\circ)^\alpha$). A comparison with 5 GHz, mostly taken from Zijlstra *et al.* (1989), follows thin free-free emission, within the 10% calibration uncertainty of the literature data. Exceptions are Hen2-142, M2-9, and SwSt 1, with 3, 5, and 8 σ excesses at 31GHz. The average of 5-31 GHz indices is $\langle\alpha_5^{31}\rangle = -0.03 \pm 0.06$.

The Sest IMaging Bolometer Array (SIMBA) operates at 1.2 mm (250 GHz, 24″ resolution). We observed 35 PNe during 3 different observing runs in 2001 and 2002, and extracted flux densities by integrating the sky intensity in a 0.6 arcmin radius. The uncertainty incorporates in a quadratic sum a 10% calibration error. The SIMBA maps confirm previous pointed heterodyne measurements obtained by L.-Å. Nyman. Our flux densities are consistent with those at 1.1 mm from Hoare *et al.* (1990), within 2 σ, for the four objects we have in common (NGC 6572, NGC 6302, M2-9, and NGC 6537).

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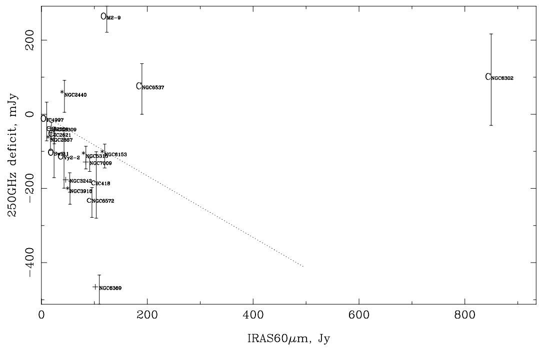

Figure 1. The $y-$axis shows the difference between the SIMBA flux density and the free-free level extrapolated from 31 GHz, and the x-axis shows *IRAS* 60μm flux density. NGC 6302 and M 2-9 are excluded for clarity.

All CBI/SIMBA objects show a deficit at 250 GHz over the free-free level extrapolated from 31 GHz, with the exception of M2-9 (7 σ excess). The excess 31 GHz emission represents ∼30–50%. Fig. 1 plots the 250 GHz deficit against *IRAS* 60μm†. The cm-wave excess does not seem related to the 10 μm dust emission features. The 250 GHz deficit is still significant when extrapolating the free-free level from 5 GHz, albeit for less objects, which may be due in part to the 10% calibration uncertainty of the 5 GHz data, but also to a 5-31 GHz spectral index > -0.15.

Is it spinning dust? If spinning dust emission accounts for 30% of the 31 GHz flux density, then $\alpha_5^{31} = 0.045$, which is consistent with $\langle \alpha_5^{31} \rangle$ within 2 σ. Spinning dust drops above 30 GHz, and is > 300 times weaker at 100 GHz.

A synchrotron component? On average the 31-250 GHz spectral index is $\langle \alpha_{31}^{250} \rangle = -0.36 \pm 0.06$, with an rms scatter of 0.16. But free-free absorption with a turn-over frequency at 40 GHz requires an absurd $T_e < 600$ K for an emission measure of 10^6 cm^{-6} pc.

The 250 GHz deficit could be interpreted as extinction from metallic needles. Using the formulae from Dwek (2004), a long-wavelength cutoff for the gray extinction of $\lambda_\circ = 1$ mm requires a needle aspect ratio l/a of ∼8000 for a resistivity of $\rho_R = 10^{-6}$ Ω cm. A unit needle opacity at 1 mm gives a total needle mass of $2\,10^{-6}$ $M_\odot$ for a grain material density of $\rho_m = 8.15$ g cm^{-3}.

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† The 10μm dust emission features compiled from the literature are indicated by 'C' for PAHs, 'c' for SiC, 'O' for silicates, '+' for weak and featureless continuum, and '*' when no data are available (data from Casassus *et al.* (2001))